Perception and Adaptation Strategies of Farmers Facing the Effects of Climate Change in Daniellia Oliveri Agroforestry Parklands in the Sudano-Sahelian Zone of Cameroon

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Abstract: The reliance of farmers in tropical countries, particularly in northern Cameroon, on rain-fed agriculture heightens their vulnerability to climate change. To align their agricultural practices with evolving climatic conditions, local farmers have developed a set of empirical indicators to assess these disturbances. However, these traditional knowledge systems have not been the subject of formal scientific study in the Sudano-sahelian zone of Cameroon, despite their critical importance to the agricultural sector. This study aims to analyze the evolution of climatic parameters within *Daniellia oliveri* agroforestry parklands to evaluate the correspondence between farmer perceptions and observed climatic variations, as well as the adaptation strategies subsequently adopted. To achieve this objective, a methodological approach incorporating surveys was employed in the Bénoué and Mayo-Rey Divisions. A total of 504 farmers operating within these agroforestry systems (252 in each Division) were surveyed using a semi-structured questionnaire. Additionally, instrumental climate data were collected from the Garoua airport meteorological station for analysis. The results indicate that the primary manifestations of climate change perceived and observed are increased temperatures and a delayed onset of rains. Quantitatively, the heaviest rainfall events were recorded in 1999 and 2008 (87 mm and 90 mm, respectively), while the highest mean annual temperatures were recorded in 2015 and 2016 (29.13 ℃ and 29.21 ℃, respectively). In terms of perception, 61.65% of farmers reported a decrease in overall rainfall, and 66.05% reported an increase in temperature. In response, farmers have developed several adaptation strategies, including limiting deforestation (31.2%), utilizing organic fertilizers (31.26%), and moderating chemical inputs (33.51%). The study concludes that policymakers should prioritize the development and support of agroforestry parklands as a key adaptation strategy for rural populations. This would enhance community resilience and reduce vulnerability to the adverse effects of climate change.

Keywords: Agroforestry Parkland; *Daniellia Oliveri*; Perceptions; Strategies; Climate Change; Cameroon

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1 Introduction

Climate change represents one of the most significant challenges confronting humanity today [1]. It is driven primarily by anthropogenic activities, including unsustainable land-use practices, compounded by natural phenomena that manifest as long-term climatic variations [2]. These variations are detectable through climate variability that persists over extended periods, with temperature and rainfall being the most sensitive parameters to these changes [3, 4]. Tropical countries, particularly those in Africa, are among the most vulnerable to climate change due to their economies' heavy reliance on rain-fed agriculture [5]. The heightened sensitivity of the agricultural sector in these regions stems from its fundamental dependence on rainfall patterns and temperature, which are intrinsically linked to the climate system [6]. To track these climatic variations and adjust their practices accordingly, farmers have developed a repertoire of empirical indicators over time. Through these indicators, they perceive changes and develop anticipatory mitigation and adaptation strategies [7]. Previous studies have shown that farmer perceptions of climate change vary across countries, agricultural policies, sectors, age groups, gender, and sociocultural groups. Consequently, the mitigation and adaptation strategies employed by agroforestry parkland managers are closely linked to their localized perceptions and are specific to their socio-ecological context. In Cameroon, a general decline in rainfall of 20 to 40% was recorded between 1961 and 2000 [8]. Annual precipitation has decreased at an average rate of approximately 2.9 mm per month, equivalent to 2.2% per decade. This decline is most pronounced during the months of March, April, June, July, and August [9]. The region of Northern Cameroon, specifically the predominantly agricultural Divisions of Bénoué and Mayo-Rey, has been significantly affected by these impacts, which are clearly perceived by local populations. Several studies have demonstrated that farmer perceptions of climate change can align with scientific trends derived from climatic data, thereby providing valuable insights for guiding decision-making on mitigation and adaptation efforts [10]. Therefore, a nuanced understanding of how managers of *Daniellia oliveri* agroforestry parklands perceive climate variability and its effects is essential for developing sustainable adaptation methods. While prior research has examined Cameroonian farmers' perceptions and adaptive measures in various regions including the highlands of the North-West and South-West [11], the peri-forest savannas of the Central region [12], and the Sudano-Sahelian zone [13, 14] a critical gap remains. To our knowledge, no study has specifically investigated farmer perceptions and adaptation strategies within *Daniellia oliveri* agroforestry parklands. Given the agricultural importance of these land-use systems, which have undergone significant transformation in recent years, this focus is crucial. Thus, the objective of this work is to analyze the evolution of climatic parameters in *Daniellia oliveri* agroforestry parklands to assess the concordance between farmers' perceptions and observed climatic variations, as well as to evaluate the adaptation strategies they have adopted.

2 Materials and Methods

2.1 Study Site

This study was conducted in the Sudano-Sahelian zone of Cameroon. The specific site is geographically located at approximately 9°17’59.54” N latitude and 13°23’54.13” E longitude, with an average altitude of 249 meters above sea level [15] (Figure 1). The region experiences a tropical climate, characterized by a unimodal rainfall pattern with a short rainy season and a prolonged dry season.

The annual mean precipitation ranges from 900 mm to 1200 mm [15]. The population is predominantly rural, with livelihoods based primarily on agriculture, livestock rearing, and trade [16]. Land use is intensive, with an occupancy rate exceeding 80% [17]. This high population density presents a significant constraint on access to land resources and limits the potential for expanding cultivated areas. Consequently, this zone is among the most severely affected by agricultural land degradation in Cameroon, resulting from land scarcity, overexploitation, and the compounding effects of climate change. Common agricultural crops include maize, peanuts, cotton, and soybeans. The area also supports livestock production, including cattle, sheep, goats, pigs, and poultry [18]. The unit of analysis for this study is the individual farm household. This unit was selected because it is at this level that key technical and managerial decisions regarding adaptation to precipitation variability are made.

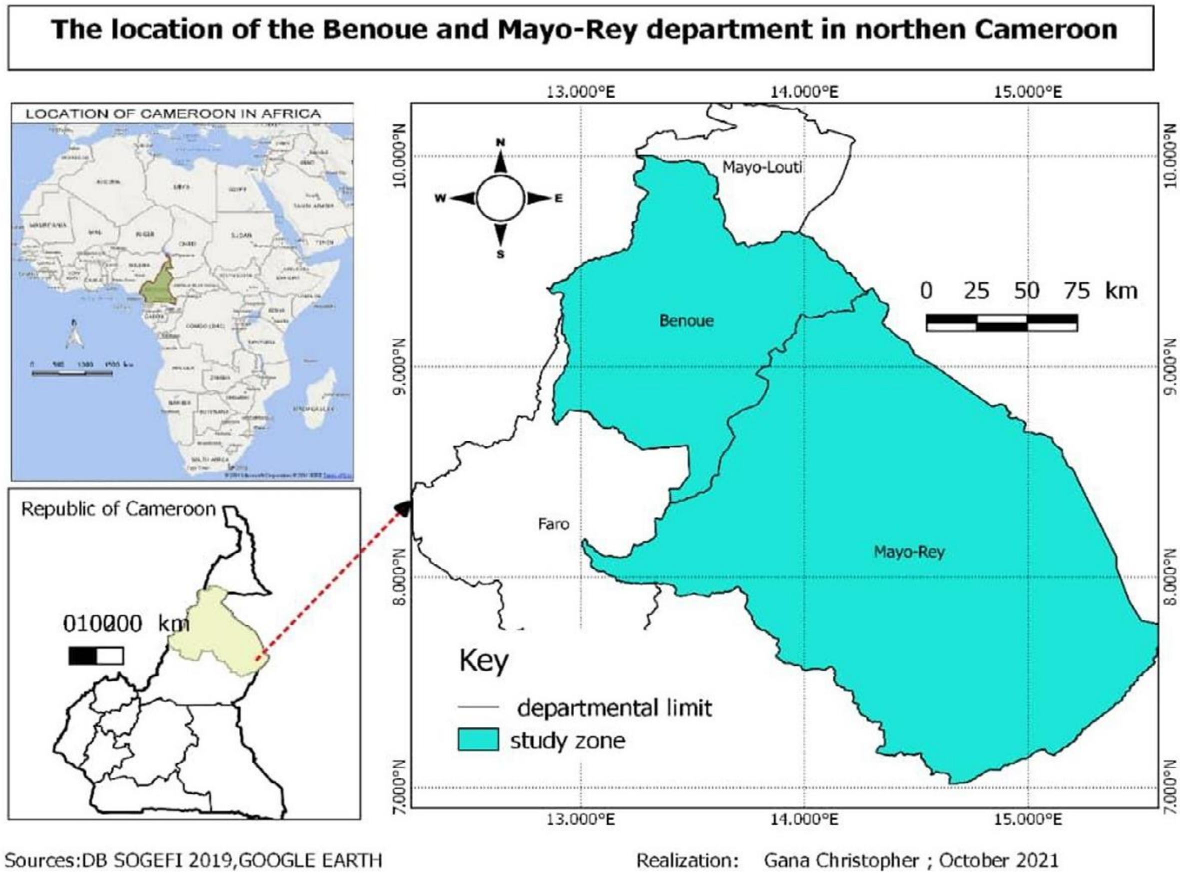


Figure 1 Map of the study area

2.2 Collection of Climate Data

The climate data, namely the monthly temperature and rainfall from 1986 to 2016, were obtained from the airport weather station. To ensure comprehension across various local dialects, data collection was conducted in two distinct phases [19]. The first, exploratory phase consisted of focus group discussions with operators of *Daniellia oliveri* agroforestry parklands. Participants were identified as key informants with the support of village development committees. These discussions served to document and clarify local knowledge of climate change, thereby informing the development of reliable survey instruments. Focus groups were organized with operators approximately 40 years of age or older, based on the premise that younger individuals might possess less experiential knowledge of long-term climate variations and thus fewer relevant observations [20]. The second phase involved the actual survey administration. Households were selected using a stratified random sampling approach, and data were collected using semi-structured questionnaires. These questionnaires were developed and refined based on insights gained from the initial exploratory phase. At the household level, respondents were selected based on their primary involvement in agricultural activities, irrespective of gender, age, or social class. Interviews were conducted individually with operators to gain an indepth understanding of their local perceptions. In total, 504 operators were surveyed across 6 municipalities in the Bénoué and Mayo-Rey Divisions. To analyze trends in climatic parameters from 1986 to 2016, statistical methods for detecting breaks or shifts within time series data were employed. The arithmetic mean was calculated to synthesize patterns in rainfall and temperature. As a fundamental measure of central tendency, the mean calculated here over the standard thirty-year period defines the climatic "normal." This value characterizes the average climatic state and is expressed as follows:

$$\bar{X}= 1 \ n \sum (xi)$$

Graphical representations have made it possible to highlight a change in the average behavior of precipitation and temperatures over time [21]. Descriptive statistics were carried out to better understand the perceptions of farmers based on climate indicators, as well as the relationship between the perception of climate indicators and their sociodemographic characteristics.

2.3 Data Analysis

The collected data were analyzed using descriptive statistics. All analyses were performed using SPSS software. Famers' indications of climate variability and farmers' perception of changes in precipitation and temperature were analysed on the basis of frequency and percentage. The objective peasant perception of variability that is, the simultaneous peasant perception of the increase in temperature and rainfall, was obtained using cross-tabulations based on frequency and percentages.

3 Results

3.1 Manifestations of Climate Change at the Local Level

Survey results indicate that farmers in both divisions perceive climate variability through distinct environmental indicators. In the Bénoué Division, a majority of operators identified the delayed onset of rainfall (20.84%) and increased temperatures (19.45%) as the primary manifestations of climate change. They further reported a perceived long-term decrease in total precipitation. Additional consequences include floods triggered by intense rainfall events (8.41%), which cause housing collapses and crop destruction. Similarly, in the Mayo-Rey Division, operators most frequently reported increased temperatures (21.62%) and delayed rainfall (17.9%) as key indicators of change. In this Division, frequent flooding (6.27%) was also cited as a significant issue, directly contributing to a decline in agricultural productivity (Figure 2).

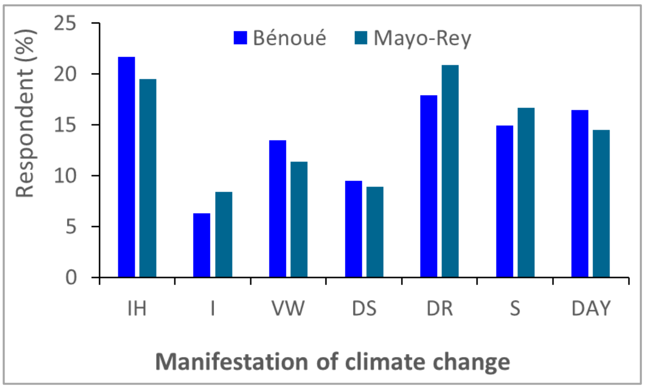
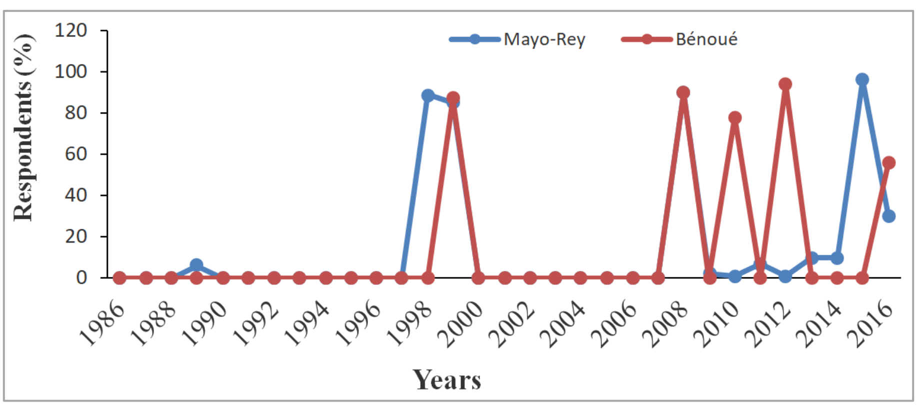


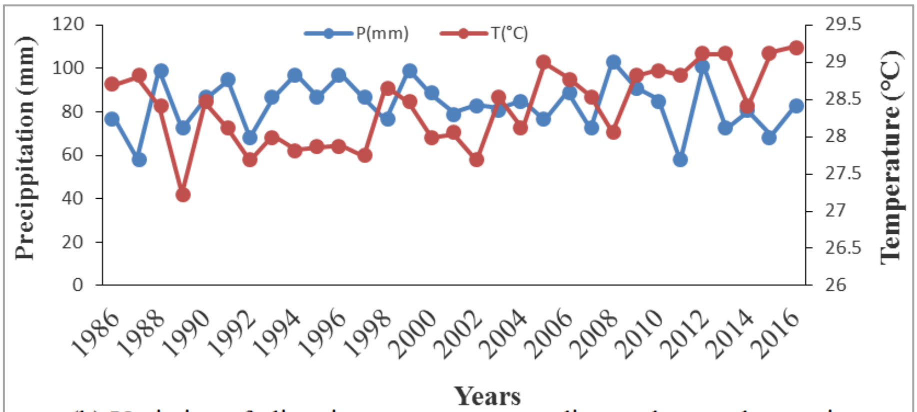
Figure 2 Manifestations of climate change at the local level

IH = increase in heat; F = flooding; VW = violent wind; DS = degradation of soil; DR = delay in rain; D = drought; DAY = decrease in agricultural yield.

3.2 Variations in Climate Parameters

Regarding variations in climatic parameters, a significant majority of operators (79.33%) reported increasingly violent winds, with a higher prevalence in Bénoué (85.74%) than in Mayo-Rey (72.91%). These wind events were cited as causing the uprooting of trees and, at times, the destruction of homes and crops. Similarly, 66.05% of all operators perceived an increase in temperature and drought, a perception again more common in Bénoué (78.47%) than in Mayo-Rey (53.67%) (Figure 3a). Respondents reported that these conditions have detrimental impacts on their livelihoods and agricultural productivity. Operators also provided recollections of specific anomalous years. In the Bénoué Division, 56.34% of operators identified 1999, 2008, 2010 and 2012 as years of particularly high rainfall. Conversely, 33.66% reported experiencing severe drought in 2005, 2013, and 2016. In the Mayo-Rey Division, 63.27% of operators indicated that rainfall peaked in 1988, 1999, 2008 and 2015, while 26.63% recalled 1986 and 2016 as years of exceptionally high temperatures (Figure 3b).





(b) Variation of climatic parameters according to the weather station

Source: Garoua airport weather station (2017)

Figure 3 Variation of climatic parameters in the North from 1986 to 2016

3.3 Causes of Climate Change

Regarding the perceived causes of climate change, survey respondents identified several key factors. Deforestation, attributed to excessive tree cutting, was cited by 40.94% of all operators as the primary driver of climate disruption. This perception was more prevalent in the Bénoué Division (45.39%) than in Mayo-Rey (36.49%). Operators explained that excessive tree removal reduces vegetation cover, thereby diminishing the area's photosynthetic capacity and its ability to regulate local climatic conditions. Other operators attributed climate change to persistent drought observed over recent years (13.56%). A further 28.89% of respondents cited population growth within villages as a contributing factor, likely alluding to associated increases in resource consumption and changes in land use (Figure 4).

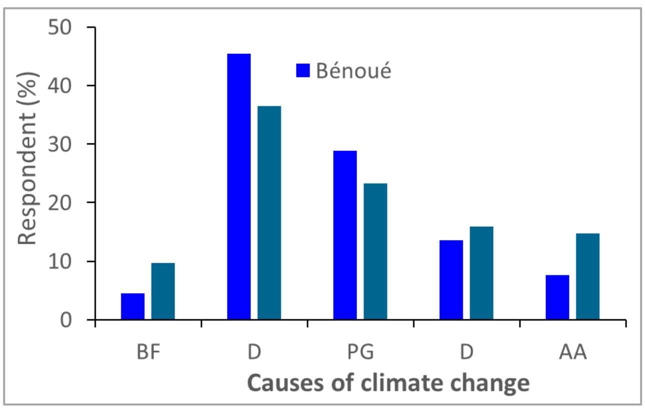


Figure 4 Causes of climate change according to the population of the area

BF = bush fires; D = deforestation; PG = population growth; D = drought; AA = agricultural activity.

3.4 Consequences of Climate Change

Climate change has direct consequences. It varie from 4% for migration to 26.5% for famine due to decreased agricultural yields and ecosystem services (Figure 5). In the Mayo-Rey Division, farmers report that the long duration of the dry season has a negative impact on the soil.

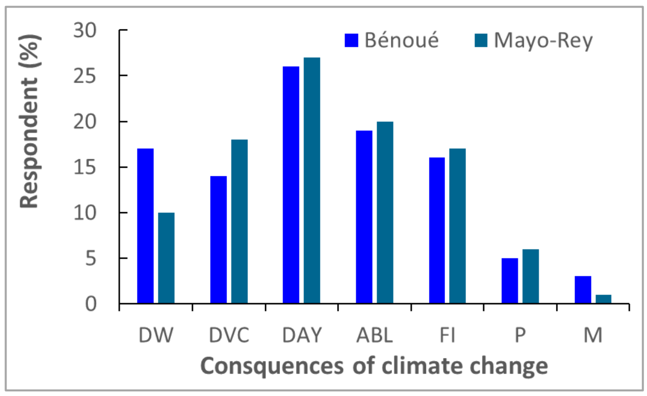


Figure 5 Consequences of climate change

DW = drying up of watercourses; DVC = degradation of vegetation cover; DAY = decrease in agricultural yield; EBL = expansion of bare land; FI = food insecurity; P = poverty; M = migration.

According to the operators (100%), the effects of climate change are clearly felt both on agricultural production and social life. Table 1 highlights all the potential effects of climate change in *Daniellia oliveri* agroforesty parkland. The most severe effects noted are: the decrease in agricultural yields (31.3%), the reduction in water availability (18.5%), the alteration of the agricultural calendar (13.4%), partial maturity of crops (10.2%), abortion of crop seeds and phytosanitary problems (26.6%). These climate changes have a direct impact on the degradation of the social living conditions of farmers and consumers in general (Table 1).

Table 1 Effect of identified climate change on crops

Nature of effects	**Crop rotation (%)**	**Phytosanitary problems (%)**	**Crop yield (%)**	**Annual culture (%)**
Increase in temperature	Reduction in availability and quality of water (21.60).	Increase in phytosanitary problems (9.97).	Decrease in yield (4.56).	Decrease in yield (2.38).
Drought pockets	Partial maturity of crops and abortion of crop seeds (6.45).	Appearance of crop enemies (4.89).	Decrease in yield (4.98).	
Duration of the dry season	Increase in the crop cycle (0.45).	Recrudescence of the cutworms at the beginning and end of the season with the ear mining caterpillars (7.86).	Decrease in yield (5.74).	Severe drop in yields (3.46). Seed abortion, nutritional deficiency (0.87).
Decrease in precipitation	X	X	Decrease in yield (0.68).	Decrease in yield (1.09).
Heavy rains	X	Rot of the production (3.97).	Loss of production (0.45).	Destruction of crops (2.4).
Delay in sowing	Partial maturity of crops (2.3).	X	Poor production (3.71).	Modification of the agricultural calendar (13.4%).

X = absence of information

3.5 Local Strategies for Mitigating and Adapting to Climate Change

The different endogenous practices developed to cope with the negative impacts of climate change ranges from 6.92% for fallowing old parks in favor of new ones to 16.78% for the use of organic fertilizers (Figure 6).

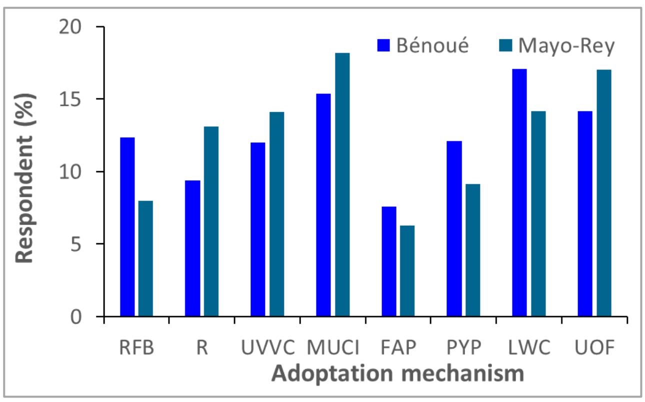


Figure 6 Local strategies for mitigating and adapting to climate variations

RFB = reduction of bush fires; R = reforestation; UVVC = use of varieties with a short vegetative cycle; MUCI = moderate use of chemical inputs; FAP = fallowing agroforestry parklands; PYP = protection of young plants; LWC = limitation of wood cutting; UOF = use of organic fertilizers.

The analysis of climate change mitigation and adaptation strategies, disaggregated by operator gender, reveals that men (56.22%) reported employing a greater number of strategies than women (43.78%). An exception to this trend was observed in the practice of fallowing agroforestry parklands, where women demonstrated higher engagement (8.5%). Reforestation and moderated wood harvesting (34.82%) emerged as the most prevalent strategies for the sustainable conservation of these parklands. When analyzed by education level, operators without formal Western education developed the most strategies (31.62%), followed by those with primary (25.13%), secondary (22.58%), and university education (20.67%). Notable exceptions to this inverse relationship were observed for specific practices: reforestation was most common among those with primary education (5.6%), the use of organic fertilizers was highest in the primary education group (5.1%), and the moderate use of chemical inputs was most frequently adopted by operators with a university education (4.8%). Regarding age, operators aged 75 years and above adopted the highest number of strategies (26.21%), followed by those aged 60–74 (21.4%), 30–44 (17.54%), and 15–29 (15.24%). Exceptions to this trend included a higher use of organic fertilizers among the youngest cohort (15–29 years = 4.8%) and a greater adoption of short-season crop varieties among those aged 30–44 (5.3%) (Table 2). In response to declining yields of main staple crops, farmers are increasingly intensifying tree intercropping within their farming systems as a core adaptation strategy.

Table 2 Sociological characteristics of operators based on mitigation and adaptation strategies

Frequency of respondents (%)									
Sociodemographic Characteristics	**RBF**	**R**	**UVVC**	**MUCI**	**FAP**	**PYP**	**LWC**	**UOF**	**Total**
Genders									
Men	3	9.22	7.31	9.17	5.01	2.81	9.16	10.54	56.22
Women	2.03	7.11	5	5.61	8.5	1.23	7.33	6.97	43.78
Total	5.03	17.33	10.31	16.78	13.51	4.04	17.49	15.51	100
Level of education									
was not at school	3.3	2.41	7.8	2.6	4	2.02	5	4.49	31.62
Primary	0.8	5.6	3.5	2.53	3.13	2.12	2.35	5.1	25.13
Secondary	2.7	3.73	2.40	3.6	3.5	1.09	3.11	2.45	22.58
University	1.23	5.34	3.5	4.8	0.7	1.5	1.97	1.63	20.67
Total	8.03	17.08	17.02	13.53	11.33	6.73	12.43	13.67	100
Age group									
[15-29]	0.9	0.67	1.98	2.35	0.5	0.09	3.42	5.33	15.24
[30-44]	0.23	2.23	4.8	1.08	2.3	0.9	3	3	17.54
[45-59]	0.4	4.5	1.4	1.8	4.71	1.2	2.1	3.5	19.61
[60-74]	1.6	3	2.8	4.1	3.5	0.8	3.5	2.1	21.4
≥75	1.9	4.3	2.31	4.8	5	1.12	2.78	4	26.21
Total	5.03	14.7	13.29	14.13	16.01	4.11	14.8	17.93	100

RBF = reduction of bush fires; R = reforestation; UVVC = use of varieties with a short vegetative cycle; MUCI = moderate use of chemical inputs; FAP = fallowing agroforestry parklands; PYP = protection of young plants; LWC = limitation of wood cutting; UOF = use of organic fertilizers.

4 Discussion

4.1 Perception of Producers Regarding the Manifestations of Climate Change

Numerous studies conducted across Africa, and in Cameroon specifically, confirm that farmers are highly exposed to the adverse effects of climate change. This vulnerability is directly linked to variability in key climatic parameters. Farmers in the Sudano-Sahelian zone of Cameroon report a multitude of manifestations. The most frequently cited include increasing temperatures, delayed onset of rains leading to decreased agricultural yields, intense rainfall events accompanied by flooding and seed rot, crop destruction, strong winds, and recurrent droughts. The prevalence of these manifestations varies across study sites. These findings align with those of Bambara *et al*. (2013) [22] on farmers' perceptions of climate change and its socio-environmental consequences in Burkina Faso. Similarly, Alle *et al*. (2013) [23] documented congruent farmer perceptions in Benin. In these studies, the manifestations of climate change were more pronounced for rainfall than for temperature. The paramount importance of rainfall is explained by its direct and immediate influence on agricultural productivity, a result consistent with those reported by Ouédraogo *et al.* (2010) [24] in Burkina Faso and Agossou *et al.* (2011) [25] in Benin. Operators of *Daniellia oliveri* agroforestry parklands report that climate change has significantly disrupted their traditional agricultural calendar. All operators (100%) surveyed in the Sudano-Sahelian zone were aware of its impacts. They report that historically, cloud cover reliably predicted rain, and the rainy season consistently began in March–April and ended in November. Presently, cloud cover no longer serves as a dependable indicator. The season now typically commences in late May or early June and concludes by October. Furthermore, nearly all operators noted that August, once considered the peak rainy month, no longer holds this distinction. In this context, Ozer *et al*. (2010) [26] emphasize that drought is a key climatic variation in the Sahel that plays a critical role in land degradation. These authors note that increased aridity exposes soils to wind and water erosion, leading to the loss of arable topsoil, the slowing of biological processes, and a consequent decline in productivity. Within the *D. oliveri* parklands, the disappearance of fragile species due to strong winds is observed. These occurrences can be attributed to the extended duration and increased intensity of the hot season over recent years. The agricultural sector maintains an intimate connection with its environment, and its dependence on the climate stems from a deep, historically informed understanding of climatic evolution [27].

4.2 Variations in Climate Parameters

This analysis of climate change perceptions was conducted in the Bénoué and Mayo-Rey Divisions within the Sudano-Sahelian zone of Cameroon. Operators in these two administrative Divisions provided observations on climatic changes, specifically through evolving parameters such as precipitation patterns, elevated temperatures, strong winds, drought frequency, and diminished cool periods. These findings are consistent with existing literature. Agossou *et al.* (2011) [25] reported similar variations across diverse agroecological zones in Benin. Similarly, the work of Ouédraogo *et al*. (2010) [24] on perceptions and adaptation strategies in the Sahelian, Sudano-Sahelian, and Sudanian zones of Burkina Faso documented variations, including decreased rainfall, seasonal disruptions, rain irregularity, drought pockets, and heavy rains causing floods. Operators of *Daniellia oliveri* agroforestry parklands are acutely aware that climate change impacts their activities. As with other parameters, perceptions of coolness and rainfall variability differ between Divisions and across years. A unanimous majority of operators (100%) in both Divisions reported a perceived long-term decrease in total rainfall. However, a slight moderating coolness is maintained on the sites, attributed to the presence of trees both in residential areas and particularly within the *D. oliveri* agroforestry parklands. This decrease in rainfall generally correlates with increased temperatures. Given its immediate impact on both the natural environment and human communities, rainfall variability emerges as a paramount concern. The results of studies by Gur *et al*. (2015) [28] and Innocent *et al*. (2016) [29] align with the rainfall variations observed in this study. Specific annual recollections from operators provide further detail: in Bénoué, 56.34% identified 1999, 2008, 2010, and 2012 as years of abundant rainfall, while 33.66% reported severe drought in 2005, 2013, and 2016. In Mayo-Rey, 63.27% of operators indicated that rainfall was at its maximum in 1988, 1999, 2008, and 2015, while 26.63% recalled exceptionally high temperatures in 1986 and 2016. Mamah *et al*. (2019) [30] report a similar effect in *Borassus aethiopum* agroforestry parklands. To some extent, operator statements overlap with instrumental weather data; for instance, 68.67% of operators agreed that precipitation was particularly abundant in 1999 and 2008, which is corroborated by meteorological records. However, discrepancies exist, as some operator recollections regarding specific years do not align with the climatic data. Recalling exact dates requires exceptional memory and extensive experience. While informants often remember the manifestations of climate change clearly, the precise chronology of these events is not always accurately retained.

4.3 Causes of Climate Change

The operators surveyed in this study identified several perceived causes of climate change. Primarily, they attribute it to rampant population growth and associated anthropogenic activities, including shifting cultivation using slash-and-burn techniques, the application of chemical inputs, and widespread deforestation. As local living conditions become increasingly harsh, populations migrate to areas with available land to establish new agricultural spaces. Tabi (2017) [31] reported similar causal factors in a study conducted within *Vitellaria paradoxa* agroforestry parklands. The situation observed in the Mayo-Rey agroforestry areas is nearly identical to that of the Bénoué Division, with operators consistently citing population growth and deforestation as the principal drivers of climate variation. Beyond these factors, a subset of operators in both Divisions expressed the belief that climate manifestations constitute a divine punishment for mankind's misconduct. Others pointed to inappropriate agricultural practices as a key cause. These findings are consistent with the work of Mukungu (2009) [32] in Burkina Faso, which demonstrated that the causes of climate change were largely attributed to population growth, deforestation, and drought. According to Diallo *et al.* (2011) [33], environmental evolution is significantly influenced by anthropogenic activities. Specifically, agricultural practices such as repeated bush fires, deforestation, overgrazing, the reduction of fallow duration, and the failure to return organo-mineral matter to the soil rapidly lead to the degradation of vegetative and soil covers. These processes promote the greenhouse effect by releasing sequestered CO_2 into the atmosphere (Bengali *et al*., 2018) [34].

4.4 Consequences of Climate Change

Operators in the Sudano-Sahelian zone of Cameroon describe numerous consequences of climate change in an area characterized by a lengthening dry season and less frequent, but more intense and unpredictable, rainfall. The analysis of climatic variation through parameters such as rainfall and temperature indicate that farmers possess a clear understanding of the environmental changes occurring within their localities. This finding aligns with previous studies on local knowledge in the context of climate variability (Sofoluwe *et al*., 2011) [35]. Operators primarily attribute environmental degradation to severe droughts, which lead to soil impoverishment and a direct reduction in agricultural productivity within *Daniellia oliveri* agroforestry parklands. Excessive droughts cause the desiccation of watercourses, wells, and boreholes. Concurrently, some operators report the delayed onset of seasonal rains. These consequences collectively contribute to heightened food insecurity; an effect corroborated by Mamah (2022) [36] in *Borassus aethiopum* agroforestry parklands. The fundamental dependence of agricultural production on rainfall explains this high level of perception among farmers. Conversely, some operators emphasize the negative impacts of prolonged rainfall on the quantity and quality of harvested products. The occurrence of violent winds results in the destruction of staple crops such as *Pennisetum glaucum* (pearl millet) and *Zea mays*, inducing severe food shortages. Heavy rainfall leads to direct damage, including the destruction of homes and crops, subsequently fostering famine due to reduced yields. In the Mayo-Rey Division, operators report that the extended dry season adversely affects soil quality, inhibiting the normal development of both crops and trees within the parklands. The severe drought observed in recent years has, according to a majority of respondents, caused mortality among some *D. oliveri* individuals and other associated species. A significant decrease in tree productivity due to climatic hazards has been noted. Furthermore, a large majority of farmers (100%) state that rains, when accompanied by strong winds, can lead to the death of woody plants. Frequent flooding causes vegetation destruction and soil alteration, resulting in low agricultural yields (Mbua, 2016) [37]. The primary impact of climate change perceived by surveyed farmers (97.56%) is intensified deforestation, which contributes to rising temperatures through increased atmospheric CO_2 concentrations. The decline in agricultural yields is largely attributed to reduced precipitation. Water is an essential element for plant growth, constituting over 80% of cell content and playing a critical role in metabolic processes and the transport of mineral elements (Thomas *et al*., 2007) [38]. Additionally, the resurgence of grasshoppers at the beginning and end of the season, along with ear-feeding caterpillars, is linked to high temperatures that favor the proliferation of diseases and insect pests (Cooper *et al*., 2008) [39]. Seed loss and reduced viability occur because seeds remaining in the soil for prolonged periods are removed by predators such as birds and rats, or they rot and die post-germination due to water stress. Finally, the modification of the traditional agricultural calendar is driven by the delayed onset of rains, compelling farmers who typically sow from March-April to postpone their initial planting dates.

4.5 Local Strategies for Mitigating and Adapting to Climate Change

In response to climate changes observed over recent decades, populations in the Sudano-sahelian zone of Cameroon have developed indigenous adaptation mechanisms to mitigate their effects. The strategies employed by producers vary according to their specific production objectives. Confronted with livelihood instability, farmers have adopted diverse approaches. In the face of climatic disruptions such as floods, decreased rainfall, and rising temperatures, many exotic species prioritize income stabilization over maximization. According to the majority of farmers surveyed across both Divisions, traditional adaptation practices developed to counter the negative impacts of climate change include the application of organic fertilizers, reduction of bushfires, reforestation, fallowing of degraded agroforestry parklands, and crop rotation. A prominent illustration is the introduction of *D. oliveri* parklands. Multiple studies have demonstrated the efficacy of organic amendments in maintaining soil agronomic quality. Additional indigenous strategies pertain to soil management, notably the simultaneous exploitation of diverse landscape units to spread risk. The delayed onset of rains has compelled farmers to adjust their agricultural practices, often leading them to select early-maturing crop varieties as a primary adaptation. Consequently, farming activities commence with the first rains to capitalize on available moisture. This aligns with findings by Amadou (2005) [40] in Niger, where producers adopted early sowing strategies to maximize water use efficiency. Similarly, Roncoli *et al*. (2000) [41] identify the use of short-cycle cultivars as a palliative measure against rainfall variability. As Kouressy *et al*. (2008) [42] note, declining precipitation has directly driven the adoption of shorter-cycle varieties better suited to a condensed rainy season. These varieties are particularly prevalent in the Sudano-Sahelian zone due to its heightened vulnerability to climatic shifts. In the Mayo-Rey Division, common strategies include limiting deforestation, reducing bushfires, and utilizing organic fertilizers. The conservation and protection of *D. oliveri* and other native species are encouraged to establish a favorable microclimate during the dry season. This strategy is predominantly adopted by women, who are more engaged in rain-fed agriculture. Older operators demonstrate a greater propensity to adopt adaptive strategies, whereas more educated operators often exhibit less knowledge of climate change, potentially due to stronger affiliations with Western paradigms; they often experience its effects without developing targeted adaptive measures [11]. The economic benefits derived from *D. oliveri* agroforestry parklands provide a strong incentive for operators to engage in their conservation and protection without external intervention. The heterogeneity of adopted strategies reflects the diverse socio-economic conditions, access to capital, institutional environments, and individual perceptions prevalent within these communities. Nevertheless, as climate change is a global phenomenon, a comprehensive response is ultimately required. The consumption and sale of non-timber forest products (NTFP) also serve as an adaptive strategy, as the generated income enables households to purchase food and other goods not produced within the parklands. In the Bénoué Division, operators have developed drainage systems to prevent flooding and minimize crop losses. To combat deforestation, initiatives such as community forests, nurseries, dissemination of improved cooking stoves, and the formation of cooperatives have been established to conserve *D. oliveri* agroforestry parklands. The indigenous strategies developed by operators in the Sudano-Sahelian zone of Cameroon are thus directly influenced by the goods and ecosystem services provided by agroforestry parklands. It is noteworthy that reactive strategies such as migration are also frequently cited in the literature as a response to climate stressors [43]. The principal adaptation strategies identified such as adjusting planting dates, utilizing improved varieties, relocating crops, and enhancing land management are consistent with adaptation options documented in the scientific literature for the agricultural sector.

5 Conclusion

This study assessed farmer perceptions and local adaptation strategies employed to mitigate the effects of climate change within *Daniellia oliveri* agroforestry parklands in the Sudano-Sahelian zone of Cameroon. The analysis reveals that operators are acutely aware of the manifestations of climate change and their detrimental consequences on livelihoods. Alterations in precipitation patterns are perceived through indicators such as declining total rainfall, an earlier cessation of rains, and a shortened rainy season. Changes in temperature and wind are discerned through increased heat intensity and the increased frequency of violent wind events. The socioeconomic conditions of the operators are significantly affected by these consequences of climate variability. The investigation into local mitigation and adaptation practices uncovered a diverse repertoire of techniques. In light of these results, it is evident that the perceptions of farmers and their corresponding adaptation strategies are highly varied. Looking forward, a promising pathway involves the integration of endogenous practices with scientific knowledge to establish a robust, contextually appropriate strategy for climate change mitigation and adaptation. Such a synergistic approach is essential for effectively reducing the adverse impacts of climate on local livelihoods and enhancing community resilience.

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Conflicts of Interest

We declare that there are no conflicts of interest associated to this manuscript.

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